Northwest **Power** and **Conservation** Council

June 5, 2018

MEMORANDUM

TO: **Power Committee**

FROM: **Gillian Charles, Mike Starrett**

SUBJECT: **Generation Resource Updates for the Mid-Term Assessment – Natural Gas Technologies**

BACKGROUND:

Presenters: Gillian Charles, Mike Starrett

Summary: As part of the Seventh Power Plan's mid-term assessment, staff is updating its estimates of resource capital costs. At the May Power Committee meeting, staff presented updated capital costs for solar PV and wind. This meeting, staff will be concluding the updates with capital cost estimates for three natural gas technologies – combined cycle combustion turbine, single cycle combustion turbine (frame), and reciprocating engine.

Staff held two Generating Resources Advisory Committee (GRAC) meetings to present and discuss the updated analysis of resource capital costs.

Relevance: Resource costs put forth by the Council are often referenced by utilities in the region during their integrated resource planning activities and a mid-term update provides a timely refresh as well as an additional snapshot for trend analysis.

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Workplan: Seventh Power Plan, Action Plan, ANLYS-13: Update generating resource datasets and models; ANLYS-18: Track natural gas-fired technology costs and trends

Seventh Plan Midterm Assessment: Draft Resource Capital Cost Estimates for Natural Gas

Gillian Charles & Mike Starrett

Power Committee

June 12, 2018

Seventh Plan Mid-Term Assessment: Generating Resources

Resource Acquisitions and Retirements

Updated Capital Cost Estimates
- Solar PV, Wind
- Natural Gas

Renewable Portfolio Standards Analysis

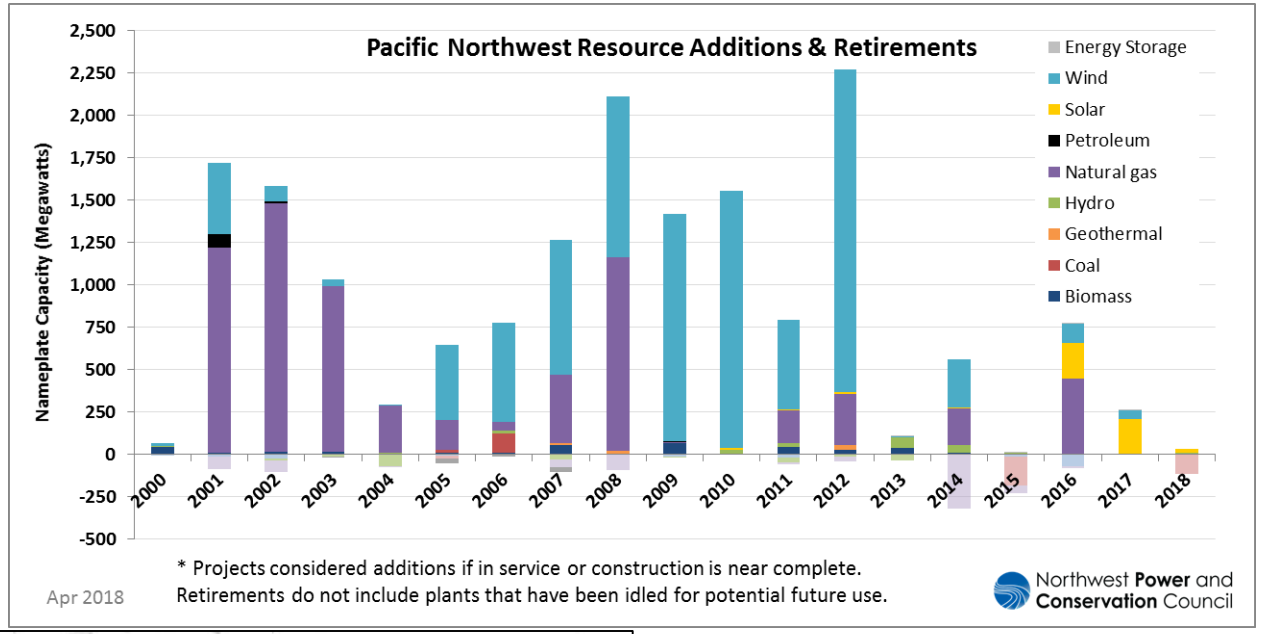
Annual CO_2 Emissions

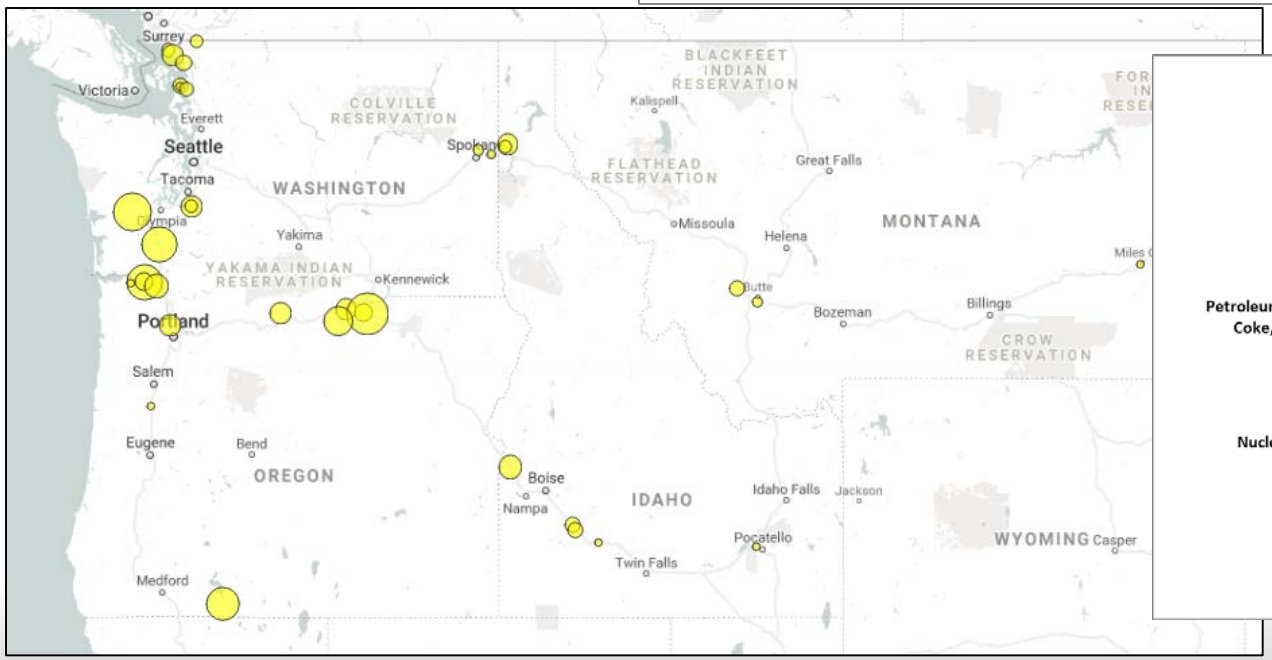
Emerging Technologies

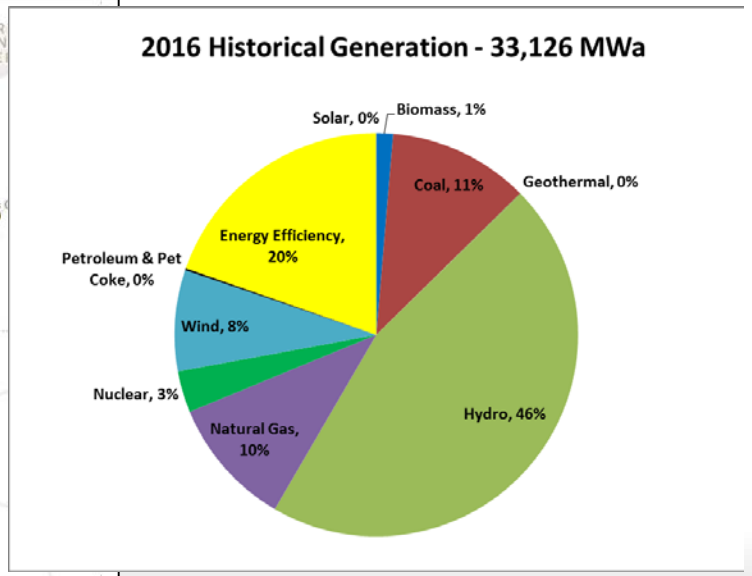
Action Plan

- Significant natural gas development following 2000-01 west coast energy crisis

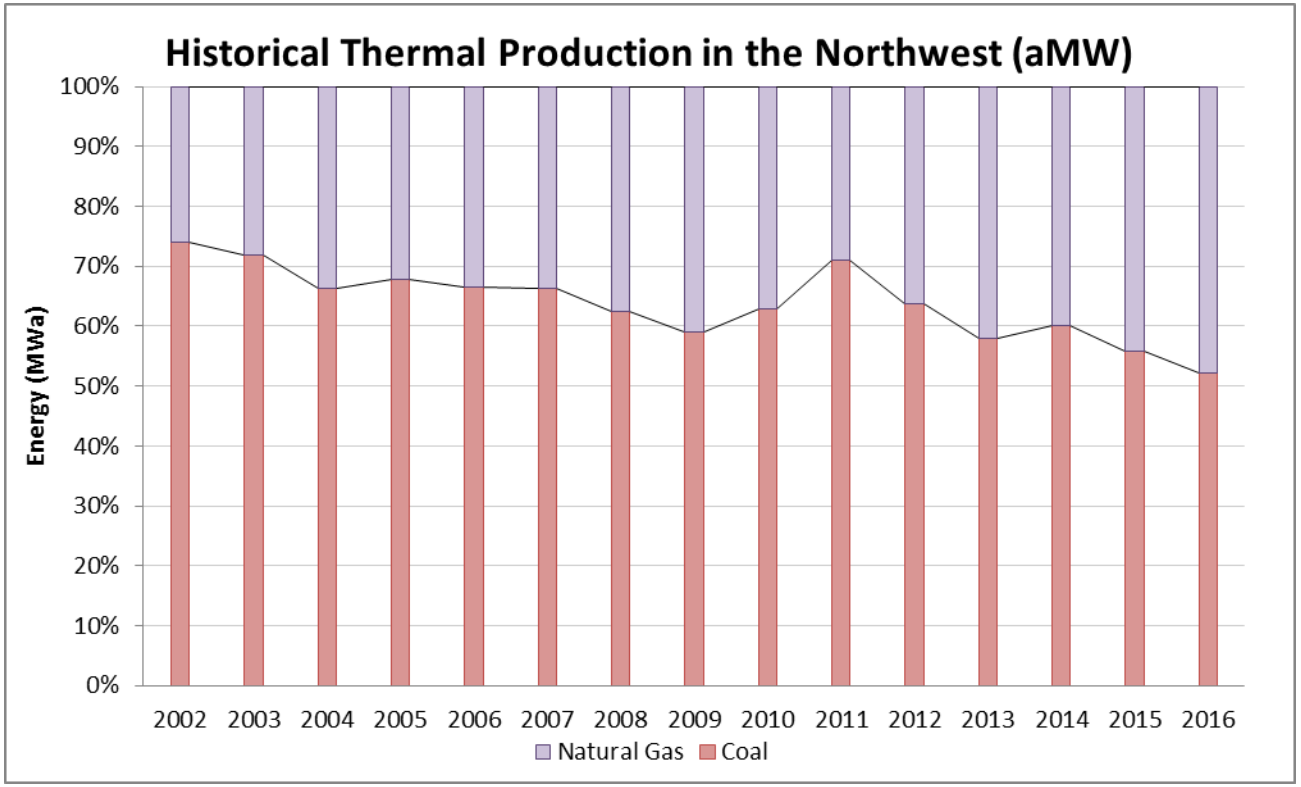
Source data: Council's project database and online map





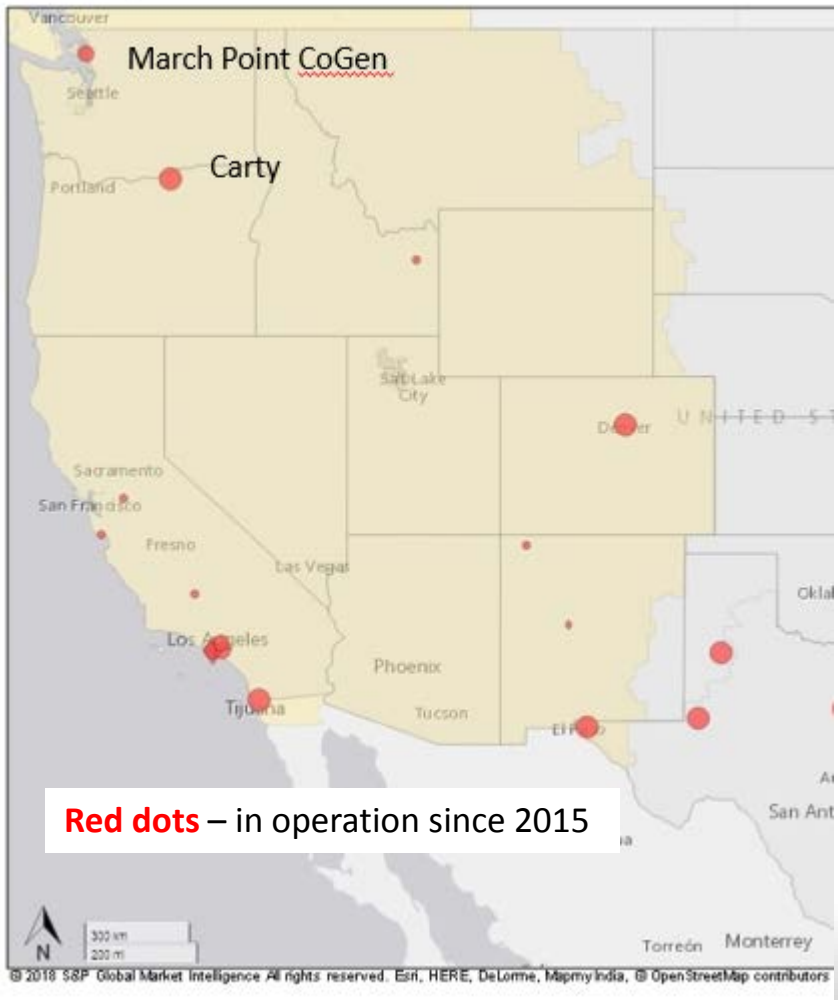


Fossil fuel production is changing



Fuel Type	Emissions (CO_2/MMBtu)
Coal	205.7 – 228.6 lbs
Petroleum/Oil	161.3 lbs
Natural Gas	117 lbs

Gas Plant Development: Around the WECC

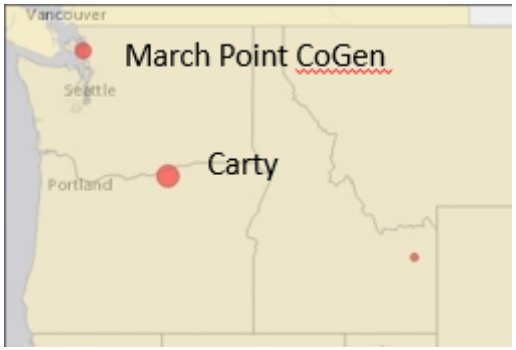


Since **2015**,

- ~3,000 MW in operation
  - ~1,500 MW CCCT
  - ~ 1,355 MW peakers (primarily aeros and intercooled LMS100; no SCCT frames)
- ~2,400 MW under construction for service by EOY 2022
- And more proposed…

Source: SNL

Gas Plant Development: In the PNW



- 440 MW
- In Service – July 2016

- Mitsubishi G-class
- 1x1

- Est. cost ~$660M

Carty Generating Station
Owner - PGE

Photo source: East Oregonian

State Carbon Legislative Efforts

Oregon

- 2018 legislative session considered a "cap and invest" policy that focused on market structure to reduce GHG emissions; policy was not adopted
- Speaker of the House and President of the Senate have pledged to pursue a state carbon policy in the longer 2019 session

Washington

- 2018 legislative session considered several proposals to put a price on carbon across economic sectors, incl. state's electric utilities; proposal did not pass the legislature
- Initiative 1631 submitted to Secretary of State in March – sets a price of $15/ton; requires 260K signatures by end of June to be added to the November ballot

Steel and Aluminum Tariffs (1)

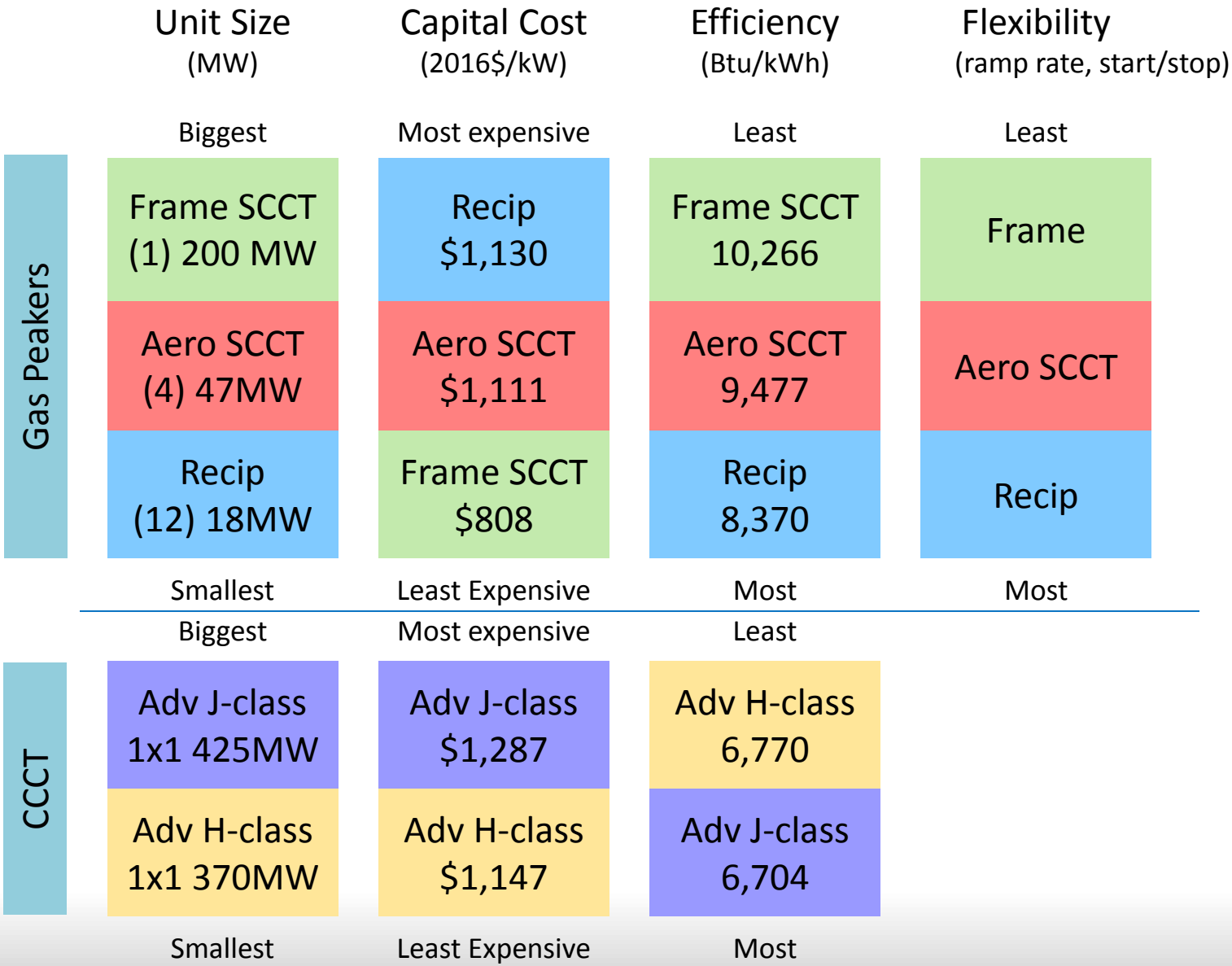
- Trump Administration announced tariffs on imported steel (25%) and aluminum (10%) in March 2018
  - Exemptions for some countries being negotiated
- Canada is the largest supplier of aluminum to the US, fulfilling about 50% of U.S. aluminum requirements (The Washington Post, 3/2/18)

http://money.cnn.com/2018/03/07/investing/ge-tariffs-trade-war-steel/index.html?iid=EL

Steel and Aluminum Tariffs (2)

- **General Electric** – "Our internal data shows our consumption of imported metals likely to be impacted by the tariffs is minimal. We are monitoring the situation as it develops." CNN, 3/7/18
- **Wartsila** – "minimal, if any, impacts" as all gensets are manufactured in Europe. John Robbins, 5/1/18
- **Siemens** – "...we do not see a big impact on our business, as far as our customers in the United States are concerned..." Siemens CEO, CNBC, 3/7/18

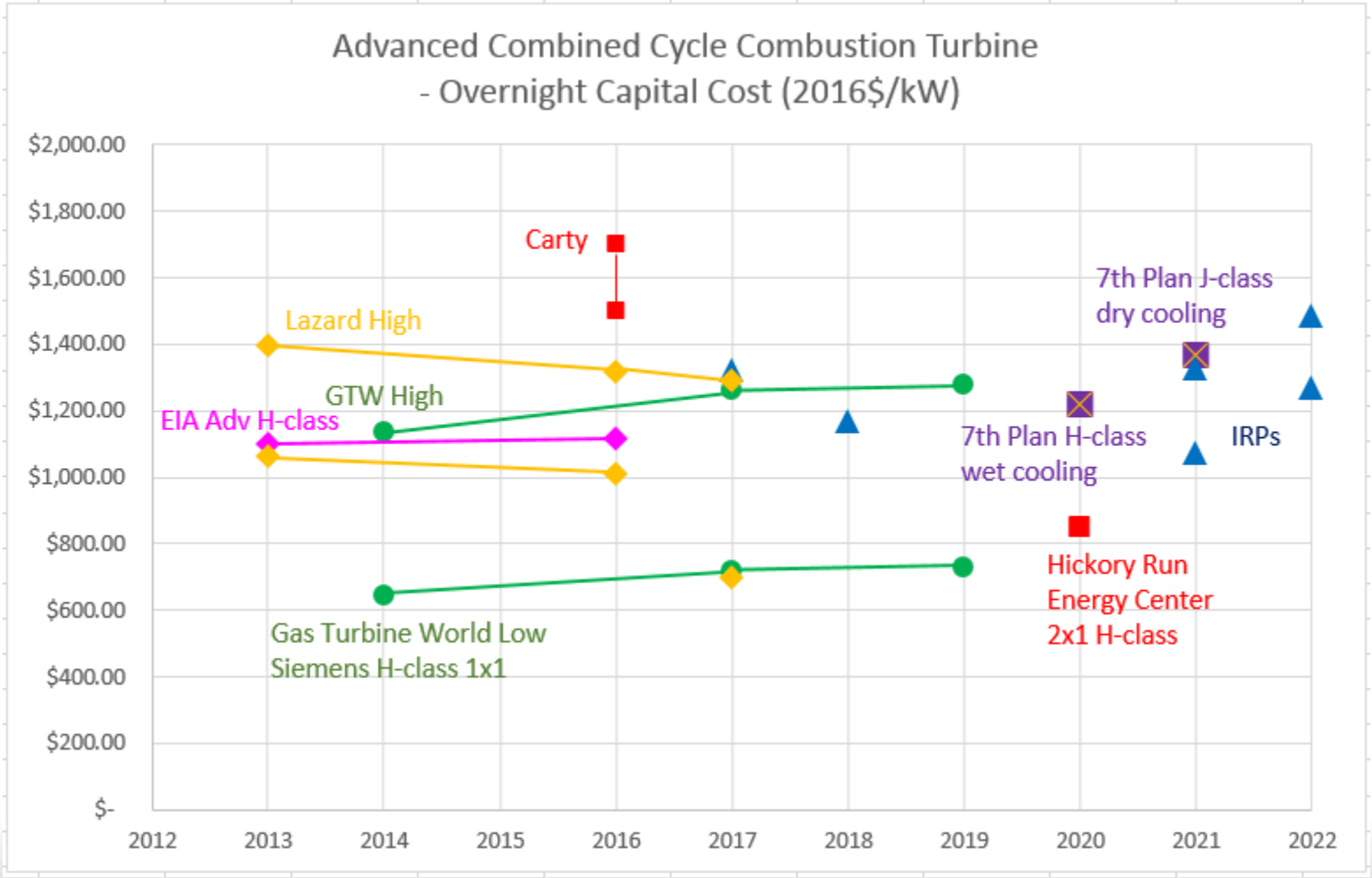
Seventh Plan Natural Gas Plants Characteristics



Reminder: How the Council develops capital cost estimates

- **Gather** analysis of available cost data from
  - "Raw": manufacturers, developers, PPAs, project-specific publically available reported info, technical handbooks (Gas Turbine World)
  - Secondary sources: Reports from EIA, DOE, national labs, IRPs, state commissions, consultants, etc.
- **Normalize** the cost data to a consistent year dollars, configuration, capacity, heat rate, etc.
- **Plot** the normalized data and look for trends and outliers – determine best estimate of current and future costs

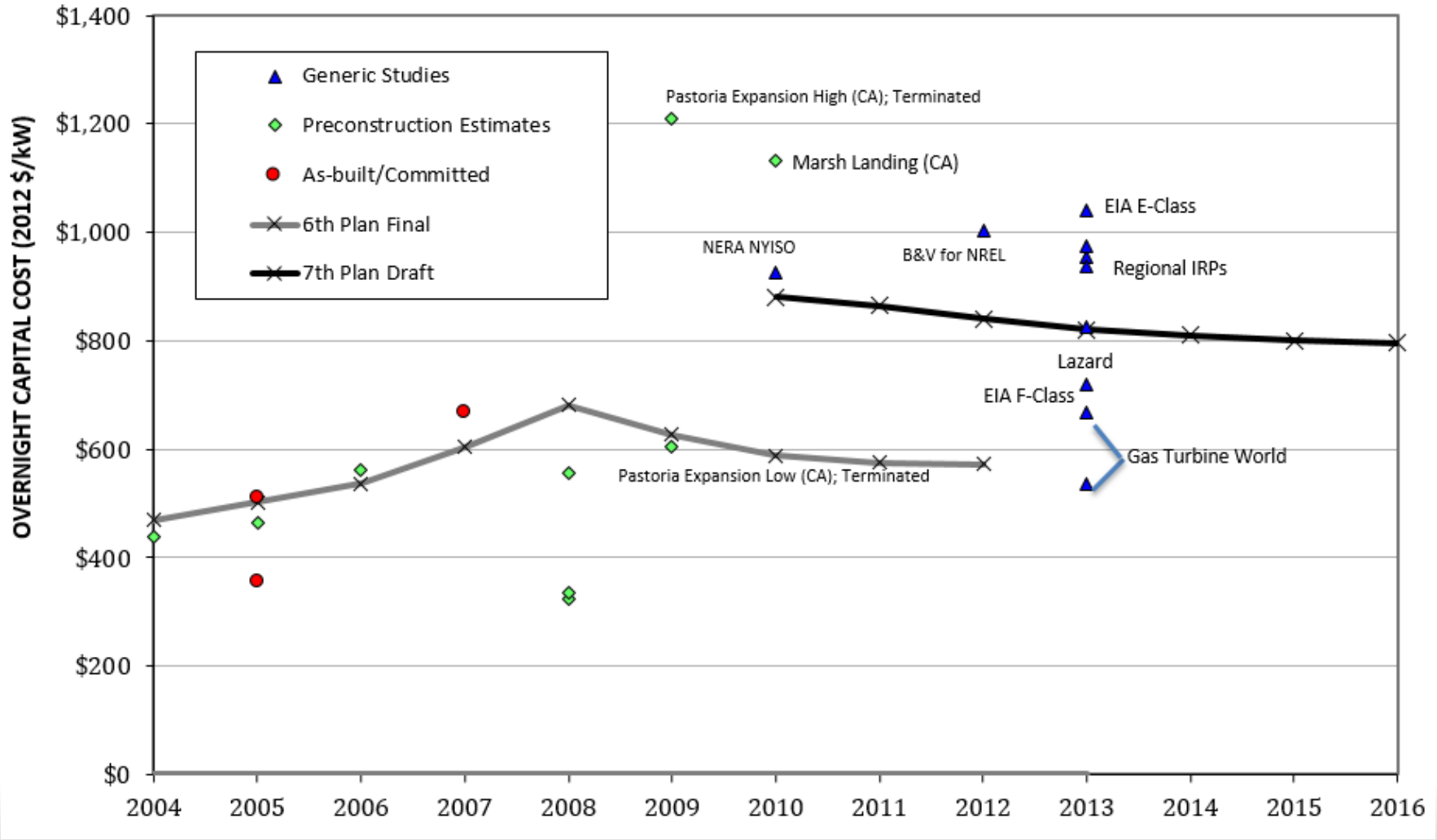
7P Midterm: Draft Capital Cost Update - CCCT



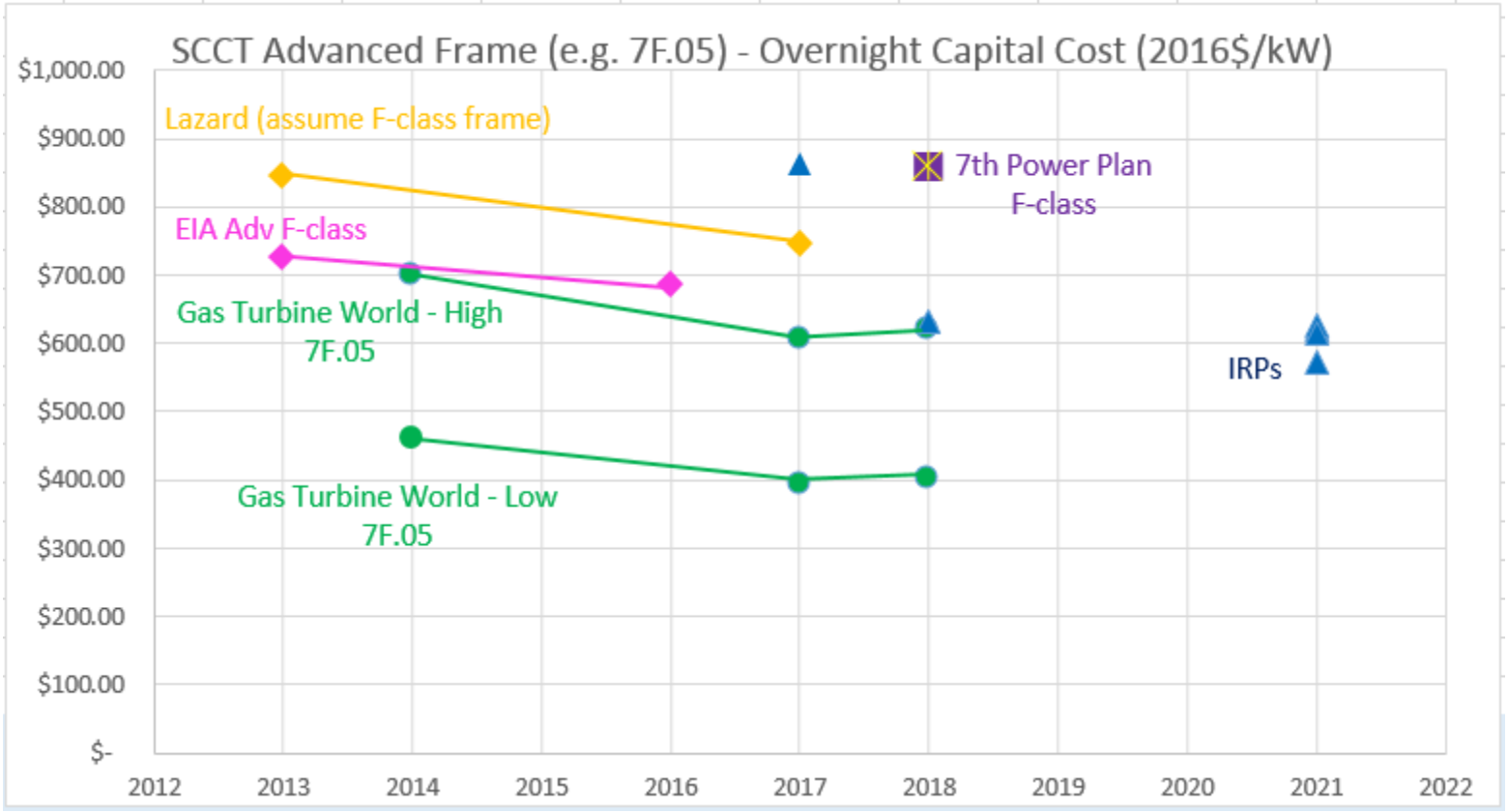
7P Mid-term Assessment Draft: CCCT

	CCCT Adv Wet Cooling	CCCT Adv Dry Cooling
Configuration	1 x 1	1 x 1
Capacity (MW)	370 MW	425 MW
Model	Siemens H-Class (SCC6 8000H – SGT6)	MHI J-Class (MPCP1 - M501J)
Location	East	East*
Transmission	BPA point-to-point	BPA point-to-point
Economic Life (years)	30 years	30 years
Financial Sponsor	IOU	IOU
Heat Rate (btu/kWh)	6770	6704
Overnight Capital Cost (2016$/kW)		
Seventh Plan Final	**$1,220**	**$1,369**
Proposed Mid-term Assessment Update	**$1,100 - $1,300**	**$1,200 - $1,400**

7P Reference Plant: Frame



7P Midterm: Draft Capital Cost Update - Frame



7P Mid-term Assessment Draft: Frame

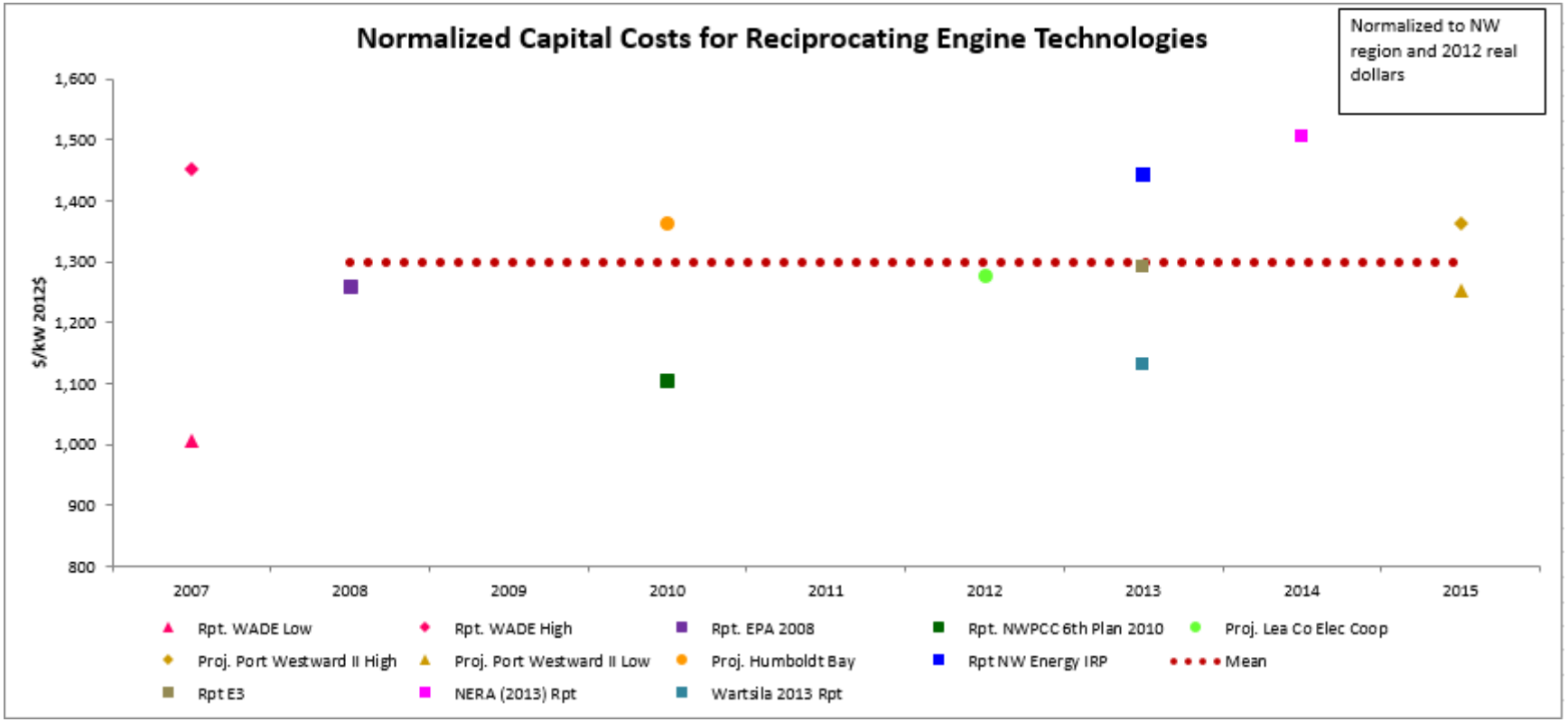
	Frame GT (East)	Frame GT (West)
Configuration	(1) GT x 216	(1) GT x 216
Capacity (MW)	200 MW	200 MW
Model	GE 7F.05	GE 7F.05
Location	East	West*
Transmission	BPA point-to-point	BPA point-to-point
Economic Life (years)	30 years	30 years
Financial Sponsor	IOU	IOU
Heat Rate (btu/kWh)	10,266	10,266
Overnight Capital Cost (2016$/kW)		
Seventh Plan Final	**$859**	**$856**
Proposed Mid-term Assessment Update	**$500 - $650**	**$500 - $650**

Potential reasons for decrease in cost:

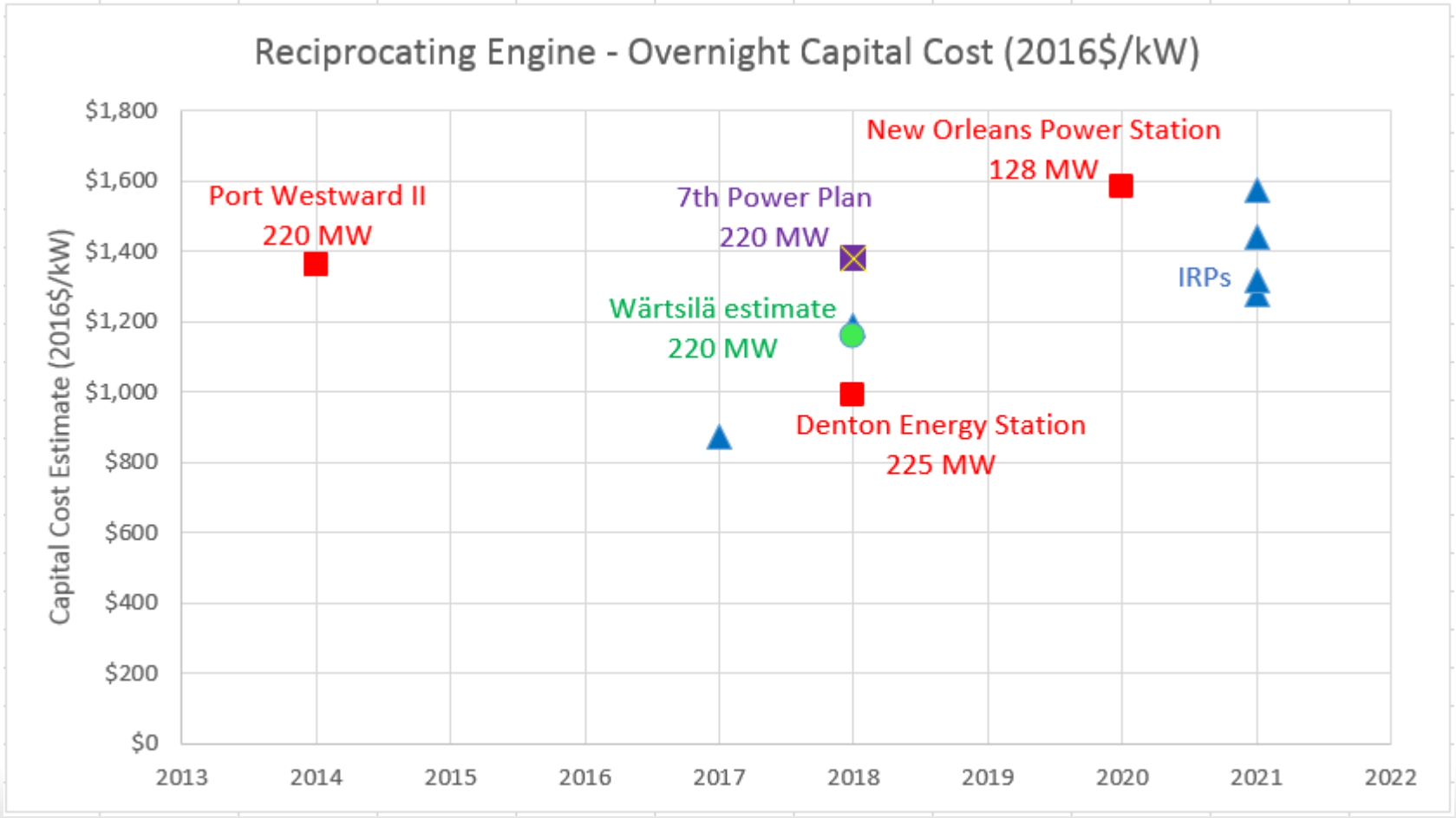
- 10-15% reductions in equipment cost (Gas Turbine World)
- Increased competitiveness amongst EPC vendors

** Staff to continue to monitor and delve into **

7P Reference Plant: Recip



7P Midterm: Draft Capital Cost Update - Recip



7P Mid-term Assessment Draft: Recip

	Reciprocating Engine
Configuration	(12) 18V50SG 18.3 MW
Capacity (MW)	220
Model	Wärtsilä 18V50SG
Location	East
Transmission	BPA point-to-point
Economic Life (years)	30 years
Financial Sponsor	IOU
Heat Rate (btu/kWh)	8,370
Overnight Capital Cost (2016$/kW)	
Seventh Plan Final	**$1,382**
Proposed Mid-term Assessment Update	**$1,250 - $1,450**

In Summary: Proposed Updates to Capital Cost Estimates for Seventh Plan Mid-term Assessment

Technology	Seventh Plan ($2016)	Proposed Mid-term Update ($2016)	Trend
CCCT Adv Wet Cooling	$1,220	$1,100 - $1,300	Slight decrease
CCCT Adv Dry Cooling	$1,369	$1,200 - $1,400	Slight decrease
Frame GT (East)	$859	$500 - $650	Decrease (30-40%)
Reciprocating Engine	$1,382	$1,250 - $1,450	No change
Wind	$2,382	$1,500 - $1,700	Decrease (30-40%)
Solar PV	$1,791 / $2,566	$1,350 - $1,500	Decrease (25-60%)

Background Slides

Properties of Peaking Technologies

Frame (80MW – 250 MW units) • Stationary device, weight not an issue • Strengths - longevity and durability • Weaknesses – slower response time; higher heat rate; higher exhaust temperatures/difficult air quality control • Typical use – on for several days, then shut down • PNW – several frame units built in 1970's – 1990's for hydro back-up (firming)	**Aeroderivative (15 – 60 MW units)** • Designed from aircraft engine; lighter, more delicate than frame • Strengths – rapid response; lower heat rate; easy maintenance; smaller unit size; can use SCR and OxyCat • Weaknesses - ??? • Typical use – meeting short-term peak loads • PNW – several Pratt and Whitney and a few LM6000 plants
Intercooled (100 MW units) • Hybrid of frame and aeroderivative → compressor intercooler • Strengths – rapid response; lowest GT heat rate; good turndown characteristics; can use SCR and OxyCat • Weaknesses - requires continuous source of cooling water • Typical use –short-term peak loads and variable resource integration • PNW – none currently planned or in operation; numerous in WECC	**Reciprocating Engine (2 - 20 MW units)** • Designed from transportation engines (locomotives and marine) • Strengths – highly modular; very rapid response, low heat rate; very good turndown characteristics • Weaknesses – historically shorter plant life • Typical use –short-term peak loads and variable resource integration • PNW – PGE building first large plant in region; several smaller plants in operation • Note: aside from NG peaking, used for small biogas and cogen applications, back-up gen

SCR – Selective Catalytic Reduction of nitrogen oxides
OxyCat – Oxidation Catalyst for carbon monoxide and hydro carbon

Gas Turbine World: Cost Variables

Altitude/Average ambient temperature

- CCCT lose power output at rate of ~3%/1,000 ft and 6%/18°F
- e.g. Plant located at 1,650ft and 77°F could cost ~11% more $/kW than ISO rated plant (fyi - Boardman ~ 300ft)

Cost of Construction by state/region

- If same plant is built in higher cost state (e.g. CA), cost of labor could be double and add ~20% to total plant cost

Environmental regulations

- Dependent on state environmental mandates, e.g. Selective catalytic reduction for NOx and CO catalyst adds ~5% $/kW

Wet/dry cooling

- Air-cooled condensers are more expensive than water-cooled, adding ~10% $/kW

GTW: Optional Equipment

Fuel compressors

- Plant specific, redundant equipment can add ~4-5% to plant $/kW

Oil back-up

- Raises price of gas turbines to include dual fuel burners, adds ~2-3%

Inlet air chilling

- Plants operating at high ambient temps, adds ~3-6%

Bypass stack

- Adding ability to start/run the gas turbine independent of HRSG, adds ~3%

Duct firing

- Can add 10-15% to total plant cost and $/kW; however on a fully-fired basis the plant is less expensive on a $/kW (more capacity) than unfired design

Gas Turbine World - CCCT

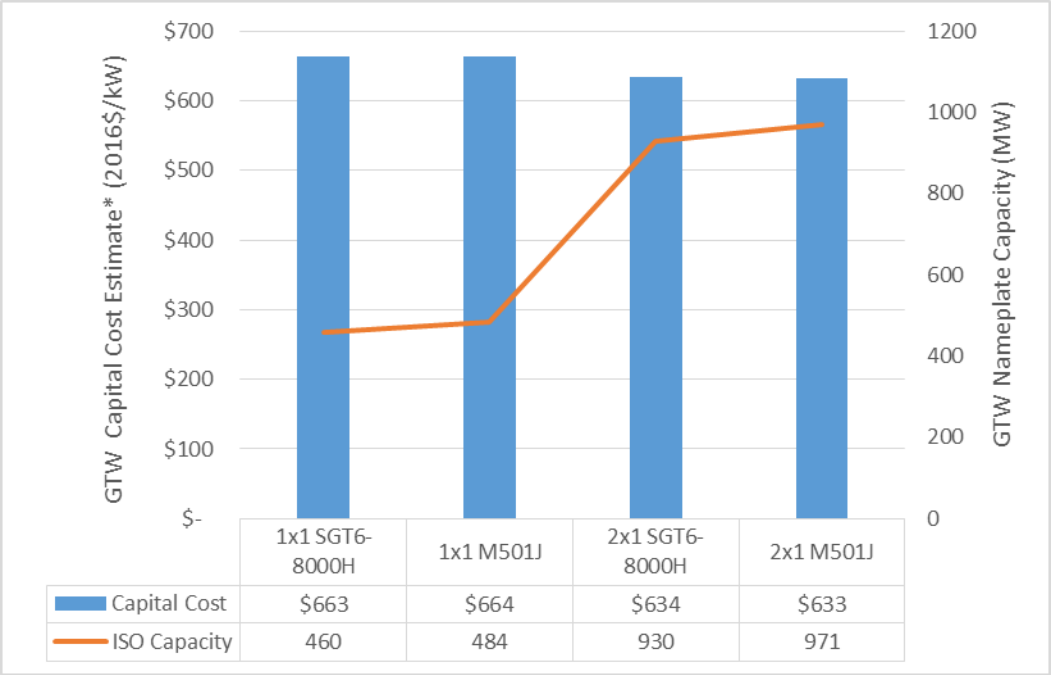
- Cost estimates for "bare bones" plants; estimate of what an EPC contractor would charge to deliver turn-key plant on owner's site
  - Excludes add-on equipment options, contingencies, owner's costs (land, legal, financing, development costs and fees)
- Output and efficiency ratings are for base load operation at ISO standard conditions

ISO = 59°F ambient temperature and sea level

- Plant is located in Gulf Coast; built w/ non-union labor
  - Benign cost and regulatory environment, highly skilled large pool of contractors

Other Considerations

- Configuration and scaling
  - 2x1 config doubles the MW output, ~5% $/kW savings



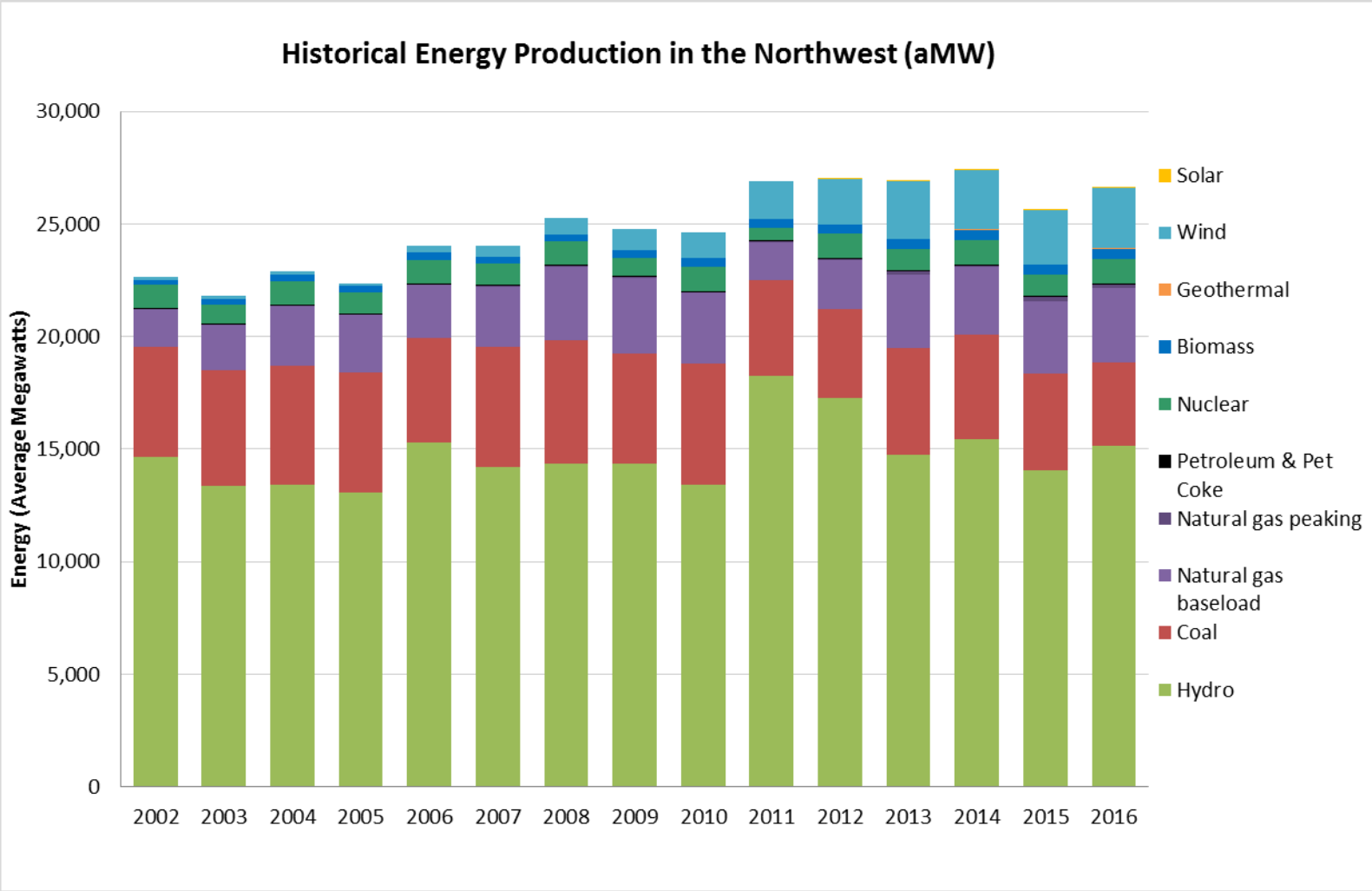
- Greenfield vs. Brownfield
  - Cost savings when plant is built on current or former site; use existing infrastructure, transmission, substation, etc.

Source data: Gas Turbine World 2016/17

Gas Turbine World - SCCT

- Prices quoted are for equipment only – do not cover transportation, plant engineering, construction, project-specific options, or owner's project costs
- Equipment scope
  - Gas turbine
  - Generator
  - Balance of plant (standard auxiliaries – air intake filter, inlet ducting and silencer, exhaust ducting, etc.)

Historical Annual Generation (1)



Regional Annual Carbon Emissions from Power Production